The effect of Roosevelt Elk on the density and distribution of conifers in regenerating forests in TFL#37 and FLA19233

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EXECUTIVE SUMMARY

Grazing and mechanical damage by Roosevelt elk (*Cervus elaphus roosevelti*) are substantial challenges to forest managers who are entrusted with the responsibility of returning logged areas to a free-to-grow status. In TFL#37 and FLA19233 on northern Vancouver Island, damage caused by elk has been a persistent problem for a number of years. Re-planting efforts, necessary to return logged areas to free-to-grow status, have been extensive. In spite of this, satisfactory regeneration has not been achieved, even in areas that have been planted up to eight times over several years.

Roosevelt elk are one of the two subspecies of elk found in British Columbia, along with Rocky Mountain elk (Blood, 2000; Cannings *et al*., 1999). Roosevelt elk are restricted almost entirely to Vancouver Island (Blood, 2000; Cannings *et al*., 1999) and northern Vancouver Island is one of the few areas in the province where elk are plentiful (Blood, 2000; Cannings *et al*., 1999). The population is estimated to be between 3000 and 3500 (Blood, 2000; Cannings *et al*., 1999) and is considered to be stable (Cannings *et al*., 1999). However, numbers are low compared to historical populations and human activity has altered and fragmented available elk habitat. The species in general is therefore considered to be vulnerable and was put on the B.C. blue-list in 1998 (Cannings *et al*., 1999).

Since populations are expected to be stable, pressures exerted by elk will continue into the foreseeable future. Given continued pressures by elk and the relative failure of current techniques to return cutblocks to a free-to-grow status, other methods must be considered. With a view to the consideration of alternative methods to compensate for elk damage, a study investigating the effect of Roosevelt elk on regenerating forest stands in TFL#37 and FLA19233 was begun in November, 2002. The intent of the study was to measure the effect of elk on the density and distribution patterns of regenerating conifer seedlings and to determine if data could be used to predict areas where high grazing intensity could be expected to occur in the future.

Twenty-one cutblocks were identified by Canadian Forest Products (Canfor) as areas in which elk browse had been problematic. The density of conifer seedlings was measured in these areas using standard silvicultural techniques. Eighteen of 21 areas were found to be satisfactorily re-stocked, but most of these areas had been re-planted numerous times. Results were therefore likely not indicative of actual browse pressures caused by elk.

Conifer distributions were measured using the t-square method (Hines and Hines, 1979) at the same 21 cutblocks and were compared to ten areas with little or no elk use. It was hypothesised that grazing would create an aggregated distribution of seedlings. The difference in the degree of aggregation was not statistically significant between the test and control areas: aggregated distributions were found at 71% of the blocks in high use areas and 50% of the low use areas, and mean values between the areas were nearly identical. It was determined that although aggregated distributions did occur in many of these areas, they were caused by factors other than damage by elk. Again, these results may have been affected by the fact that many of the test areas had been re-planted numerous times.

Data were collected for the purposes of creating a model that would predict areas likely to experience high elk use in the future, but creation of the model was determined to be beyond the scope of the current study. Potential methodologies are presented that may be used to achieve this goal in future work.

Possible alternatives to compensate for browse pressures when planting future cutblocks may be useful. These include planting in clumps, altering conifer species composition, using debris piles and planting alternative non-coniferous browse species.

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1. INTRODUCTION

Forest managers are often faced with the challenge of balancing conflicting values. Maintaining wildlife values on lands administered by Canadian Forest Products Ltd. (Canfor) has always been critical to their operations. While Canfor supports ongoing efforts at maintaining wildlife populations, there are often associated costs. Roosevelt elk (*Cervus elaphus roosevelti*), for example, place extreme pressures on regenerating forest stands through browsing and mechanical damage on conifers. Canfor, like other public land administrators, is legally responsible for assuring that cutblocks attain a free-to-grow status following logging. Therefore, logged cutblocks must be re-stocked with a suitable density and species blend of trees that are large enough to escape competition from other plants and browse pressures from elk and other ruminants. This requirement can often lead to extensive and expensive efforts to return areas to a suitable stocking standard. As a result, some blocks have been planted up to eight times without reaching a free-to-grow status, causing Canfor considerable expenditure.

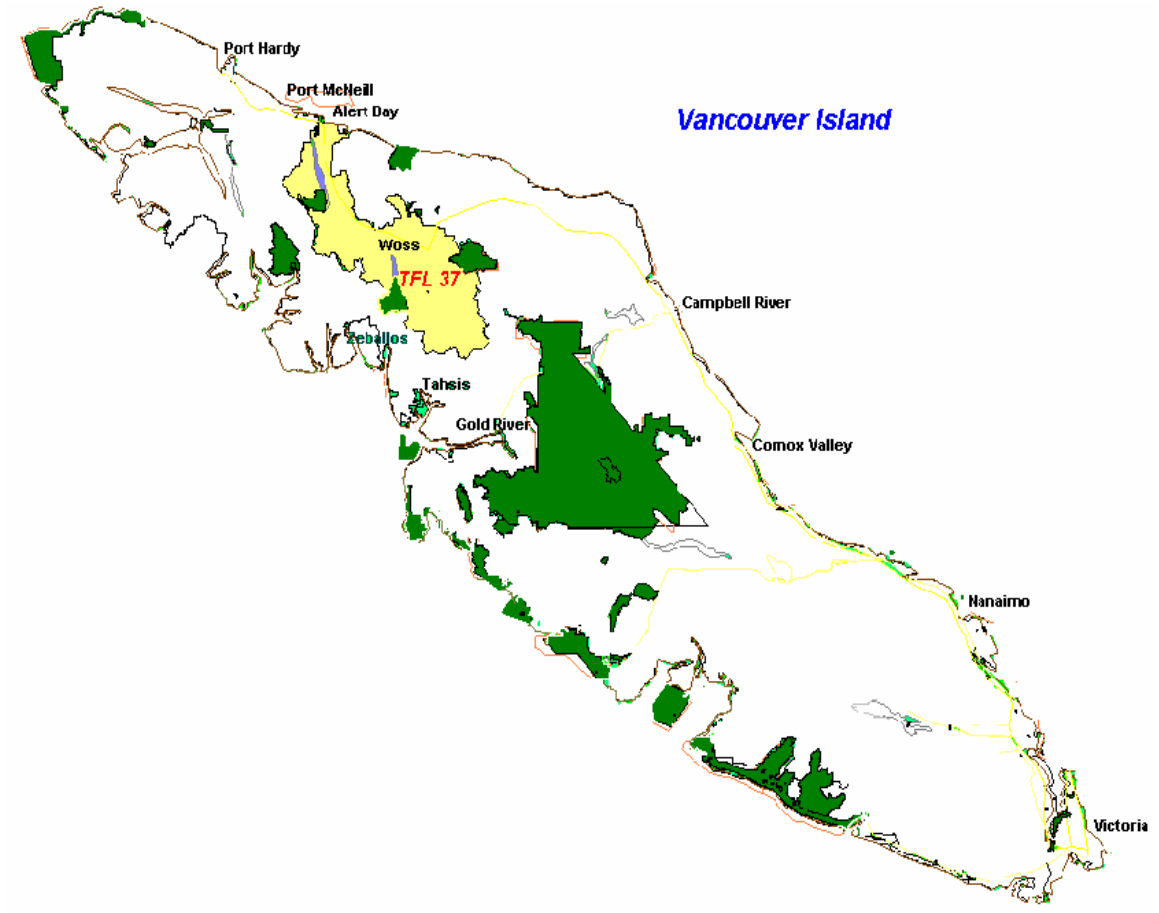

Figure 1. Location of TFL#37 on central northern Vancouver Island (map source: Canfor).

The effect of grazing by elk and other ruminants on regenerating forest stands has been well documented. It is known to decrease the survival rate of preferred browse species and cause a prodigious loss in biomass (Ammer, 1996). In northern Wisconsin, for example, Anderson & Katz (1993) estimated that *Tsuga canadensis* (eastern hemlock), a browse-sensitive, shade tolerant tree, took about 70 years to reach an equivalent stage of growth achieved in 27 years in a browse-protected forest. Browse by elk had the greatest impact on Aspen regeneration in Rocky Mountain National Park of all the variables measured including fire suppression, natural succession, fluctuations in beaver populations and climatic fluctuations (Baker *et al*., 1997). Another study in Oregon found that the exclusion of browsing by three mammal

species, including elk, significantly increased the height, stem, and crown diameter of two common willow species (Brookshire *et al*., 2002). In this case, browse damage was so extensive that the average size of the willows outside the exclosures did not increase over the five year period of the study

WRM Resource Consulting (hereafter "WRM") was contracted by Canadian Forest Products Ltd. to study the distribution and effects of elk use on regenerating forest stands in Tree Farm License (TFL) 37 and FLA19233, Vancouver Island, B.C. (Figure 1). The intent of the project was to a) measure the effect of Roosevelt elk damage on the density of well-spaced and acceptable tree species in young regenerating stands in which elk use had been identified as problematic; b) measure the effect of elk damage on the spatial distribution of regenerating trees in these same stands, specifically with respect to whether elk damage created a clumped tree distribution within these stands; and c) determine if data could be used to predict those areas within the Nimpkish Valley, before harvest, where elk damage could be expected to be most likely and / or severe.

Young regenerating forests in which elk damage was considered to be substantial were identified by Canfor staff. These areas formed the basis of the study. Field data was collected by WRM and Canfor staff. Well-spaced tree density was estimated using standard silvicultural regeneration (regen) plots following B.C. Ministry of Forests guidelines. Tree spatial distribution was measured using t-square plots (see Methods), and described using macro plots (see Methods). Predictions of areas of high probability of elk damage were based on observation, local knowledge, and review of other studies of elk distribution within and outside of the Nimpkish Valley.

Twenty-one cutblocks were identified by Canfor Staff as areas of high elk damage. Regen plots showed that well-spaced stems per hectare (SPH) varied from 320 to 1000 (mean=774.75, SE=27.57) and that 18 of 21 test blocks were satisfactorily re-stocked (i.e., the density of saplings in that area met the minimum stocking standard set in the silviculture prescription). T-square plots were conducted in 21 test blocks where elk damage was considered to be high and 10 low use areas where there was determined to be little to no elk damage. The results showed no difference in spatial distribution of trees between test and comparison blocks. The Hines statistic (h_t), which tests the hypothesis of a random spatial arrangement in the study population (Hines and Hines, 1979), ranged from 1.20 to 1.65 in the test blocks and 1.27 to 1.68 in the low use areas. An h_t value of 1.27 represents a random distribution of organisms, while lower values indicate a uniform pattern and higher values indicate an aggregated pattern (Krebs, 1998). Twelve of twenty-one test blocks and five of ten low use blocks showed clumped tree distributions, but the average Hines statistic was nearly identical for the two groups (test=1.43±0.03; low use=1.41±0.05). The preliminary conclusion is that aggregated tree distributions do occur in regenerating forest stands but that they are caused by some factor other than elk damage.

Current and historical elk distribution in the Nimpkish Valley was found to be widespread. Observation and reviews of other studies suggested that elk tend to use low elevation, low gradient areas preferentially over others, but the labour required to test this hypothesis proved to be prohibitive, given the scope and time restrictions of this project.

2. METHODOLOGY

2.1 Site selection

Twenty-one areas (hereafter referred to as test areas) were identified by Canfor staff as having a high level of historic elk use and damage. In some cases test areas covered an entire cutblock, while in others, areas of high use within the cutblocks were identified for sampling. The test areas ranged from 4.5 to 36ha, and were mainly located in the southern end of TFL#37 in the Nimpkish Valley and the upper Oktwanch River, with the exception of two areas located in the Artlish River drainage. The test areas were located where historic elk activity in Canfor's operating area has been the highest.

2.2 Regen plots

Regen plots were laid out in each area of interest on a 100x100m grid to an approximate minimum of one plot per hectare. In the cases where the test areas were less than 10ha in size, plots were usually laid out on a transect that bisected the area, with plots laid out at regular distances to assure a minimum of one plot per hectare; this arrangement was chosen for smaller areas because it was more difficult to locate one plot per hectare on a 100x100m grid in these areas. In all cases, plots were systematically located on maps before visiting the sites, thereby avoiding plot location subjectivity.

Regen plots were conducted according to the BC Ministry of Forests silviculture guidebook produced by the Forest Resources Branch (2002) and Canfor guidelines. WRM personnel conducted all regen plots following training by Canfor personnel. Data compilation and analysis was conducted by Canfor personnel and provided to WRM for interpretation.

Control plots were not conducted for the regen plots because Canfor has extensive regen plot data that could be used to compare against test block results. Additionally, the purpose of conducting regen plots was to determine if the test areas met the minimum stocking standards set by the B.C. Ministry of Forests, and to conduct growth and yield estimates. These estimates will be calculated by Canfor, and will be based on data collected during this survey, although the results are not presented here.

2.3 T-square plots

T-square plots were laid out on a grid or transect, depending on the size of the test area. The density of the plots for each area was based on the size of the grid or transect so that a total of at least 30 plots was attained for each test area. For example, if a transect was 750m long, t-square plots would be located every 25m for a total of 31 plots.

T-square methodology followed Hines and Hines (1979). Plots were located using a compass and hip chain. The distance from the plot to the nearest tree was measured, and then the distance between the first tree and its nearest neighbour was measured, given that the angle formed between the plot centre, the first tree, and its nearest neighbour was greater than 90˚. If the angle formed between the two trees and the plot centre was less than 90˚ , the second tree was disqualified in favour of the closest tree that would satisfy the 90˚ rule. Only trees greater than or equal to 1m in height were included in the t-square plots.

The data was analyzed using the Hines test for randomness of t-square data (Hines and Hines, 1979). The Hines statistic (h_T), tests the hypothesis of a random spatial pattern by comparing the sum of the distances between the plot centre and the first tree with the sum of the distances between the first and second trees. Low values of h_T indicate a uniform pattern while high values indicate aggregation. At a sample size of 30, any site with an h_T greater than 1.35 is considered to have a clumped distribution, while a value of 1.27 indicates a random distribution and smaller values indicate a uniform distribution (Krebs, 1998).

At each t-square plot, surveyors also noted the apparent site use and impact caused by elk based on evidence of browse, scat, trails, hoof prints, trampling and / or bedding, within the area directly surrounding the plot. This allowed measurements to be classified based on apparent damage and facilitated the mapping of apparent use zones following collection of the data. It was not possible to differentiate between damage caused by elk and deer, but the latter is considered to be much less widespread than the former in the study area and was therefore considered unimportant for the purposes of this study.

In addition to the test areas that were sampled, t-square plots were also performed at ten control areas where there was little to no apparent damage due to elk use. This allowed a comparison between areas with differing degrees of apparent elk damage.

2.4 Macro plots

Macro plots were designed to depict the characteristics of the regenerating stand with regard to the effect of damage by elk use, with special emphasis on the presence, number, and size of clumps of coniferous trees found within the plot. These plots were intended as a descriptive, rather than statistical, account of the general test area characteristics. Data collected included the general characteristics of the stratum, including slope, aspect and composition of the adjacent polygon, a site summary describing the area and the degree and extent of damage caused by elk, and the number, size and composition, and spatial distribution of tree clumps. The definition of clump was considered to be a group of three or more coniferous trees, of any species, equal to or greater than 1m in height, with overlapping crowns. Important portions of the B.C. RISC Forage Use Form, EM-7 (Anon., 1996), were also incorporated into the sampling form, including percent cover and condition of key shrubs and trees. The term key shrubs and trees refers to those plants that are either numerically or spatially abundant or are apparent targets of browse by Elk; condition refers to the apparent health and or level of damage of the species being assessed, relative to non-browsed individuals. Following the EM-7 form, the first five most abundant or "important" (i.e., targeted by Elk for browsing) shrub and tree species were enumerated. Each macro plot was also photographed to provide a visual record.

Macro plots were located on maps previous to visiting the site. At least one of every ten regen plots was chosen as a location for macro plots, to a minimum of one macro plot per 10ha or per test area. Macro plot locations were chosen to be roughly central to the areas of interest; where more than one macro plot was done in a test area, locations were chosen to attempt to adequately represent the variety of conditions that occurred on that site. Macro plot radii were 10m. This size was chosen because a smaller plot size would likely not have represented the general characteristics of the site.

2.5 Predictive model

An attempt was made to identify characteristics of those areas used most frequently by elk. This would allow forest managers to predict where elk damage will be highest in the future so contingency plans can be made for those areas. Information was gathered from many sources including local knowledge, information gathered while conducting the field component of this study, and the results of a two-year elk telemetry project.

The intention was to gather data with regards to where elk do and do not occur, then run a multiple regression to determine what characteristics of those areas are important in predicting where elk are most likely to occur. It was learned, however, that elk are widely distributed throughout the study area. This suggested that it was not possible to predict elk use based on a small number of predictive variables without conducting extensive data collection.

3. RESULTS

3.1 Site Selection

Twenty-one test areas were chosen as having high levels of damage due to elk use (table 1). They ranged in elevation from 150 to 725m and in size from 4 to 32ha. Ten areas were also chosen as control areas for t-square plots. They ranged in elevation from 225 to 675m and in size from 6 to 102ha.

Test and control blocks were widely dispersed across the landscape. Test blocks included all available Biogeoclimatic (BGC) subzones within the Coastal Western Hemlock (CWH) zone. The Mountain Hemlock zone was not sampled because elk activity is typically low in those areas. The CWHxm2 and CWHmm1 subzones occur at low elevations in the Nimpkish Valley, and elk activity within them is historically high. No control blocks were selected within these subzones due to the problem of finding areas that had not been affected by elk use.

Some of the test areas were found to have little apparent damage due to elk use within them. In cases where this occurred, it was noted and the survey was completed. Specifically, these areas included AR201, KO048A, KT205 and M034. Additionally, some areas had high damage, but it was not consistent across the site. In these cases, areas of high, moderate, low and no damage were delineated and the surveys were completed as usual.

Table 1. Test and comparison blocks with BGC subzones, elevation, area, number of times planted and proportion of block in high, medium, low and no use zones.

BLOCK	BGC UNIT	ELEVATION (m)	AREA (ha)	# TIMES PLANTED	PROPORTIONAL USE			
					H	M	L	N
TEST BLOCKS								
AR199	CWHvm1	160	8	4	**0.61**	0.06	0.14	0.19
AR201	CWHvm1	250	10	1	0	0.25	0.19	**0.56**
CE002	CWHvm1	350	10	2	**0.70**	0.25	0.05	0
HR046	CWHvm1	400	13	3	0.41	**0.44**	0.15	0
HR085	CWHvm2	700	12	4	0.41	**0.59**	0	0
HR087	CWHvm2	675	25	1	0	**0.67**	0.33	0
J010A	CWHmm1	200	12	1	0.33	0.18	0.06	**0.42**
K301	CWHmm1	200	18	2	0.08	**0.64**	0.26	0.03
K304	CWHmm1	250	23	2	0.23	0.23	**0.28**	0.26
K305	CWHmm1	200	4	2	**1**	0	0	0
KO048A	CWHmm1	225	8	3	**0.63**	0.04	0.33	0
KT205	CWHvm1	400	18	1	0	0	0.41	**0.59**
KV006	CWHmm1	275	14	4	**1**	0	0	0
KX024	CWHvm1	350	32	1	0.28	**0.42**	0.19	0.11
KX048	CWHvm1	375	8	3	**1**	0	0	0
KX050	CWHvm1	410	27	1	**0.56**	0.21	0.15	0.08
KX107	CWHvm1	400	10	2	**0.69**	0.29	0.03	0
M034	CWHvm2	625	7	2	0.08	**0.58**	0.26	0.08
TS040	CWHvm2	725	16	1	**0.47**	0.11	0.37	0.05
Y046	CWHmm1	325	9	2	0.41	**0.57**	0.03	0
Y051	CWHvm1	325	10	8	**0.89**	0.05	0.03	0.03
CONTROL BLOCKS								
D015	CWHvm1	225	6	1				
GC007	CWHvm1	325	27	1				
HR085	CWHvm2	675	75	1				
J011WF	CWHvm1	625	10	1				
K209	CWHvm2	625	102	1				
KH053	CWHvm1	425	36	1				
Q025	CWHvm1	550	34	1				
SW053	CWHvm1	475	51	1				
TN006WF	CWHvm2	675	6	1				
WG019	CWHvm2	625	26	1				

Other areas were mostly or entirely damaged by elk use. These blocks include K305, KV006, KX048 and Y051. All four of these blocks were flat, at low elevation and adjacent to a major stream.

3.2 Regen plots

Regen plot results were compiled based on treatment units within each block, and additionally on areas identified as high elk use areas, given that there were at least 5 plots (the minimum for regen plot compilation) within the high use areas.

Table 1. Regen plot results. TREAT. UNIT = treatment unit or high elk use area; TOTAL SPH = total stems per hectare; WS SPH = well-spaced stems per hectare; LCL = lower confidence limit for WS SPH; S/U = satisfactorily / unsatisfactorily re-stocked; TREES DAMAGED = percentage of trees in plot damaged by browse or mechanical injury (i.e., trails, bedding, etc.); BROWSE SPP = contribution of each species to the total number of trees browsed and / or mechanically damaged.

BLOCK	TREAT. UNIT	TOTAL SPH	WS SPH	LCL	S/U	TREES DAMAGED (%) BROWSE	TREES DAMAGED (%) MECH.	BROWSE SPP (%)
AR199	S2	1822	466	273	U	8.5		Ba6, Cw33
AR199	HIGH USE	1040	320	64	U	n/a		n/a
AR201	3	1857	857	773	S	n/a		n/a
CE002	S2/1	2970	800	647	S	12.0	0.6	Hw61, Cw33, Ba6
HR046	S1/3 - S3	4587	768	650	S	6.0		Cw43, Ba35, Hw22
HR046	HIGH USE	4461	769	631	S	n/a		n/a
HR085	M1/4	7181	845	779	S	3.7		Yc75, Ba25
HR085	HIGH USE	5800	760	346	S	n/a		n/a
HR087	M1/3	10109	740	661	S	2.6		Yc93, Ba7
HR087	HIGH USE	13320	840	712	S	n/a		n/a
J010A	A	4816	1000	891	S	2.0		Cw63, Fd25, Bg12
J010A	HIGH USE	4142	971	783	S	n/a		n/a
K301	A2/4	2926	905	812	S	11.0	1.4	Cw53, Hw28, Fd19
K301	HIGH USE	2942	900	794	S	n/a		n/a
K304	A1 - A3	14145	809	702	S	2.0		Cw86, Hw9, Fd5
K304	HIGH USE	1888	666	502	S	n/a		n/a
K305	A2/3	1840	700	474	U	26.0		Cw42, Fd42, Ba16
KO048A	S2/3	5125	912	699	S	0.9		Cw100
KV006	S1 - S2	2236	581	373	U	37.0		Hw40, Cw31, Ba24
KT205	A B C	4700	457	249	S	3.0		Hw33, Ba33, Fd22
KX024	S5/3	2690	810	673	S	6.0	0.7	Cw100
KX024	S1/3	3764	817	676	S	6.0	0.3	Cw61, Hw32, Bg5
KX024	HIGH USE	4335	721	636	S	n/a		n/a
KX048	S1/2	7450	962	810	S	5.0		Cw79, Ba14, Hw7
KX050	S1/4	3075	778	653	S	15.0		Cw91, Yp9
KX050	S5/3	5929	855	754	S	2.0	0.5	Cw100
KX050	HIGH USE	4460	810	718	S	n/a		n/a
KX107	S1/2 - S2/1	3272	800	649	S	10.0		Cw72, Ba17, Hw6
M034	M2	4314	800	696	S	1.3	0.6	Hw100
TS040	M1	8975	679	580	S	6.0	0.2	Yc96, Ba
TS040	M1/4	5960	640	431	S	3.0		Yc93, Hw7
TS040	HIGH USE	6973	660	513	S	n/a		n/a
Y046	A1	8000	850	685	S	4.0		Cw75, Fd25
Y051	S2/3	2963	763	558	S	5.0		Cw89, Hw11

Table 2 shows the abbreviated results of the regen plot compilation. Where there was variable elk damage within the blocks and there were enough plots within the high use areas, these areas were compiled separately as "high elk use". Note, however, that where the entire block had high use or where there were not enough plots, no "high elk use" area was compiled separately. Complete results can be found in Appendix 1.

Only three of twenty-one (14%) test areas were unsatisfactorily stocked[1]. These areas include AR199, K305 and KV006. High elk use areas made no difference to the stocking status of the areas – in no case where the overall block was sufficiently stocked was the high use area unsatisfactorily stocked. In addition to the high use areas shown in Table 2, four blocks, K305, KV006, KX048 and Y051 were mostly or entirely considered high use areas. This makes a total of fourteen high elk use areas that had a sufficient number of regen plots for compilation. Of these fourteen, three, or 21%, were unsatisfactorily stocked.

Damage to trees from elk use (pests column) ranged from none to 37% of the trees within the regen plots. Western red cedar (*Thuja plicata)* and Yellow cedar (*Chamaecyparis nootaktensis*) were the species most often targeted by elk. Those blocks that were unsatisfactorily stocked had among the highest levels of elk damage to the regenerating trees. Crop vigour was fair to excellent, with most areas falling in the good range (Appendix 1).

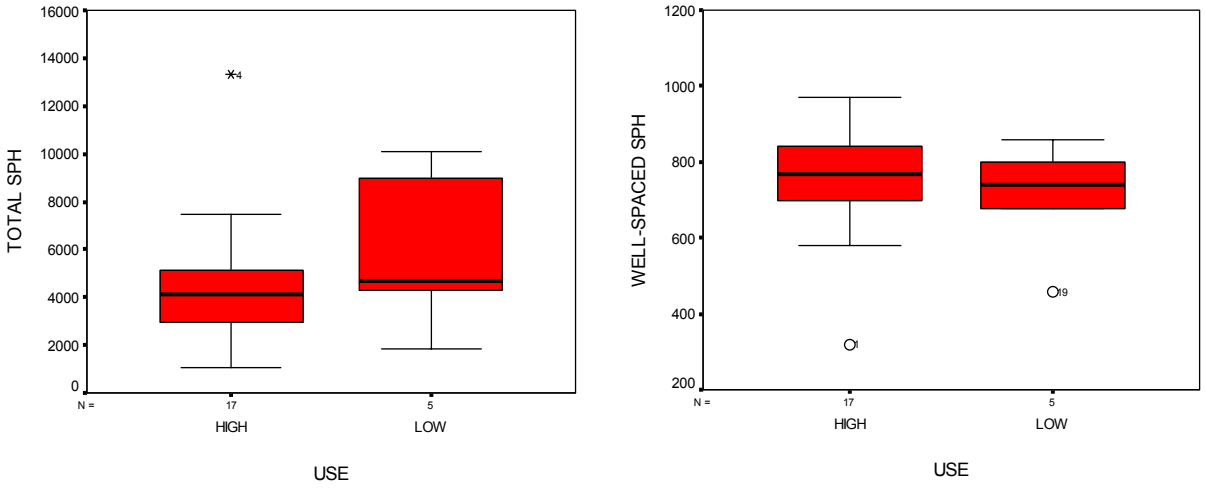

Figure 2. Box and whisker plots showing mean, standard deviation and 95% confidence intervals comparing total and well-spaced stems per hectare between high and low use areas.

Box and whisker plots showed that there was substantial overlap between high and low use areas in terms of both total stems per hectare and well-spaced stems per hectare.

3.3 T-square plots

[1] Unsatisfactorily stocked means that the density of saplings in these blocks did not meet the minimum stocking standards set in the silviculture prescription prior to harvest. Note, however, that these plots are used for an explorative purpose only and do not cover the entire block in investigation. They are not legal surveys and therefore cannot be used to determine Canfor's legal responsibility to meet minimum stocking standards for that block. The term 'not sufficiently re-stocked' (NSR) describes the status of the block according to legal surveys, conducted separately by Canfor personnel, and is explicitly avoided in this report

A total of 762 t-square plots were conducted in test areas and 300 were conducted in control areas. The results of the t-square analyses are presented in Table 3. The notable trend is that there are nearly as many control blocks that show a clumped distribution as there are test blocks. In addition, when only those plots that land within high elk use areas are used in the Hines statistic calculation, the h_T values change little, and sometimes decrease. Pearson's Product-Moment Correlation coefficient (t = 0.62, df = 19, p-value = 0.54) and Kendall's rank correlation tau (normal-z = 1.37, p-value = 0.17) both showed that h_T values were not correlated with age of the block.

Table 3. T-square plot results. Bold h_T values indicate a clumped distribution. *High only includes only those plots in high elk use zones. **NS = not significant.

BLOCK	h_T	# PLOTS	P-value	h_T	# PLOTS	P-value
TEST BLOCKS				HIGH ONLY*	HIGH ONLY	
AR199	**1.47**	36	<0.005	**1.39**	22	<0.05
AR201	**1.45**	32	<0.005		0	
CE002	**1.35**	40	<0.05	1.32	28	NS
HRO46	**1.52**	34	<0.005	1.37	14	NS
HR085	**1.56**	49	<0.005	**1.56**	20	<0.005
HR087	**1.46**	42	<0.005		0	
J010A	**1.39**	33	<0.01	1.28	11	NS
K301	1.30	39	NS**	1.19	3	NS
K304	1.32	43	NS	1.30	10	NS
K305	1.21	40	NS	1.21	40	NS
KO048A	1.33	27	NS		0	
KT205	1.29	27	NS		0	
KV006	**1.45**	39	<0.005	**1.45**	39	<0.005
KX024	**1.62**	36	<0.005	1.23	10	NS
KX048	**1.50**	32	<0.005	**1.50**	32	<0.005
KX050	**1.36**	48	<0.025	**1.38**	27	<0.01
KX107	**1.42**	35	<0.005	**1.46**	24	<0.005
M034	**1.65**	38	<0.005	**1.54**	3	
TS040	**1.47**	57	<0.005	**1.62**	27	<0.005
Y046	1.29	37	NS	1.27	15	NS
Y051	**1.54**	37	<0.005	**1.44**	33	<0.005
COMPARISON BLOCKS						
D015	1.26	30	NS		0	
GC007	**1.62**	30	<0.005		0	
HR085	1.34	30	NS		0	
J011WF	**1.58**	30	<0.005		0	
K209	1.28	30	NS		0	
KH053	**1.36**	30	<0.05		0	
Q025	**1.38**	30	<0.01		0	
SW052	1.29	30	NS		0	
TN006WF	**1.67**	30	<0.005		0	
WG009	1.33	30	NS		0	

3.4 Macro plots

Forty macro plots were completed. Summarized results are presented in Table 4; complete results are available in Appendix 2. Photos were taken of most macro plots, as well as block overviews of most test areas, and are presented in Appendix 3.

Of the forty macro plots, just over half of them fell in areas designated as high elk use. The average number and area covered by coniferous tree clumps is quite similar between the various use zones. The average slope in the high use zones was less than half that of the no use zones. Red rot coverage was highest in the high use zones and the average area covered by shrubs and herbs increased from the high to the no use zones. Grass (fm. Poecaea) was most often cited as having the first or second highest coverage in the high use zones while *Vaccinium* spp. had the second highest coverage in the high use plots and the highest coverage in the medium zone. The plot numbers in the medium and low use zones were too low to make conclusions about the most common vegetative species.

Table 4. Summary of macro plot results. CLUMP % / PLOT refers to the average area covered by coniferous tree clumps per plot; VEG. SPP. #1, 2 and 3 refer to the herbaceous vegetation species most often found among the first two species with widest coverage in the plot. For example, in 60% of the high use plots, grass is found among the first two species with the greatest coverage. VACC = *Vaccinium spp.*; SALM = Salmonberry (*Rubus spectabilis*); FIRE = fireweed (*Epilobium angustifolium*). PLANT COVERAGE refers to the percentage of the block covered by the three most numerous non-tree vegetative species.

ELK USE	HIGH	MED	LOW	NONE
#PLOTS	21	9	6	4
# CLUMPS / PLOT	3.00	3.11	3.00	3.01
CLUMP AREA / PLOT	19.13	20.81	21.36	18.56
CLUMP % / PLOT	0.06	0.07	0.07	0.06
SLOPE	5.2	7.6	6.6	10.6
RED ROT %	8.48	5.38	5.91	5.83
VEG. SPP. #1	GRASS (60%)	VACC (67%)		
VEG. SPP. #2	VACC (30%)	FIRE (56%)		
VEG. SPP. #3	SALM (25%)			
PLANT COVERAGE	41.77	44.56	43.99	49.73

Conifer leader length samples were also taken at each macro plot, but are not presented here because it is one of the criteria that was used to estimate damage caused by elk use. Presenting these data could therefore be misleading. Additionally, trees used in the leader length measurements were chosen by surveyors and may have been subjectively chosen.

Both Pearson's product-moment correlation coefficient ($t = 2.90$, $df = 19$, p-value = 0.0092) and Kendall's rank correlation tau (normal-$z = 3.359$, p-value = 0.0008) showed that the average area covered by clumps per block increased with years since the block was initially planted.

3.5 Predictive model

Data, with regard to elk distribution within this study area and similar areas, were collected from literature and local knowledge, and observations gathered while conducting this study.

Denise Koshowski (1999) conducted a study of elk distribution using aerial and ground telemetry in the Nimpkish Valley in 1996 to 1998. The results of her study are summarized in her report, available in Appendix 4. Ms. Koshowski catalogued more than 1600 elk locations over two years. These locations include UTM coordinates and were used to estimate home ranges. The UTM coordinates and home range estimates are both available in Canfor's database. Her study focused on the Upper Nimpkish watershed,

upstream from Woss, and therefore did not include the entire area covered by Canfor's claim. Although the focus of her study was not on the geographic characteristics of elk habitat, her results appear to show that elk are widespread throughout valley bottoms within the study area. The highest elevation of any of the telemetry readings in the study was 1025m.

Information was collected from local hunters and forest managers familiar with elk distribution within Canfor's Claim. Jason Shade, a forestry technician with extensive knowledge of elk distribution in the study area, identified areas within Canfor's claim where elk are known to exist. These areas have been mapped and are included in Appendix 4. The maps indicate that there are very few low elevation areas within the study area in which elk are not found.

John Deal, RPBio, RPF, Canfor's Ecosystem Management Forester was also contacted with regard to elk distribution in the study area. Mr. Deal has extensive knowledge of the distribution of several species, including elk, in this area. John Deal concurred with Jason Shade's estimate of the elk home ranges in the area. Specifically, Mr. Deal stated that there are very few watersheds within the study area where elk cannot be found, with the exception of the Kilpala River and Karmutzen River drainages.

4. DISCUSSION

Twenty-one test areas were chosen by Canfor for investigation into the effect of elk damage on the population and distribution of regenerating coniferous trees within TFL#37 and FLA19233. Apparent damage from elk use ranged from low to very high, with some areas showing spatially limited damage and others showing widespread damage. Three of twenty-one test areas were found to be unsatisfactorily stocked based on regen plot results. T-square results found no difference in aggregation of coniferous trees over one metre tall between the test areas and ten control areas within the same landscape. Macro plot results suggested that the number of coniferous tree clumps and the area covered by those clumps did not change between apparent use zones. They also suggested that slope was lower in high use zones, and that red rot coverage was higher.

The first objective of this study was to measure the effect of damage by Roosevelt elk on the density of well-spaced and acceptable tree species in young regenerating stands in which elk use had been identified as problematic. The effect of elk browse and mechanical damage on regenerating trees is apparent and well known in TFL#37, as well as other areas. It can decrease the regeneration rate of tree and shrub species directly through herbivory of the affected species (Ammer, 1996; Anderson and Katz, 1993; Baker *et al*., 1997; Brookshire *et al*., 2002), therefore preventing development of canopy cover in some species and suppressing secondary succession (Riggs *et al*., 2000). Indirect effects on tree species are likely important as well. Grazing can affect species composition of competing vegetation (Augustine and McNaughton, 1998) and can alter the amount of total and exchangeable nutrients such as calcium, magnesium and nitrogen (Hobbs, 1996; Riggs *et al*., 2000).

The number of areas found to be unsatisfactorily stocked in this study was lower than expected. This may not be surprising considering that these blocks were intensively re-planted (table 1) up to a total of seven times (block Y051). If these blocks had not been re-planted, it is thought that the effect of elk use on the population of regenerating conifers would be more apparent. The design of this study may have therefore been unsuitable for detecting the effect of elk damage on the density of regenerating trees. A more appropriate methodology may be to create exclusion areas within newly planted blocks and compare growth rates and densities of regenerating trees with unprotected areas over a period of several years. Elk grazing in southwestern Oregon was found to peak from six to eight years after reforestation and to become light within 11 to 12 years (Harper, 1968). An effective study of elk damage would therefore ideally last up to 12 years. Clearly, this is beyond the scope of the present study.

Interacting effects such as herbivore density (Kie and Lehmkuhl, 2001), characteristics of preexisting vegetation (Adler *et al*., 2001) and the timing and frequency of browse, as well as soil nutrient cycling (Augustine and McNaughton, 1998) can also confound results, and make interpretation difficult. In fact,

Hobbs (1996) found that most of the change caused by ungulate browse resulted from indirect effects on plant growth and distribution, most notably by changing the form and availability of nitrogen in the landscape.

The effects of elk damage on regenerating tree distributions were somewhat less ambiguous. Most (71%) of the test areas showed a clumped tree distribution, ranging from moderately (CE002) to highly (M034) clumped. However, the degree of clumping did not appear to correlate with the level of apparent damage caused by elk. For example, M034 had the highest h_T value (1.65), but only three of 38 plots were considered to be within high use areas. K305, in comparison, had high levels of elk damage throughout, but had the lowest h_T values in the study. Additionally, when only the plots that fell within the high use areas were included in the calculations, a smaller proportion (53%) of the test areas were found to be significantly clumped (table 3). This could be due to the smaller sample size within high use areas only, but the h_T values also often decreased when only the high use areas were included (table 3).

The t-square results from the control blocks further support these results. Half of the control blocks were found to have a significantly aggregated distribution of coniferous trees. Three blocks in particular, GC007, J011WF and TN006WF had very high h_T values with TN006WF having the highest h_T values of all the areas sampled.

The description of clumping in the macro plot results also suggests no difference in clumping between the various use zones. While the t-square test tests for the spatial distributions of individuals within a landscape, the macro plot results describe the proportion of an area covered by overlapping tree crowns. Thus the two describe related, but somewhat different, qualities of a landscape. Although the macro plot results are descriptive rather than statistical, it is worth noting that there was no apparent difference between the various elk use zones with regard to the number of clumps per plot or the area covered by clumps per plot. The macro plot results are therefore consistent with the t-square results. However, age affected the macro plot estimation of clumping, because the two were found to be highly correlated. This is simply because larger trees, having larger crowns are more likely to overlap.

These results suggest that while some areas do exhibit a highly clumped distribution of conifers, it is likely due to some factor other than damage caused by elk use. Aggregated distributions appear to be natural in the regenerating forest environment. It was often noted during this study that western hemlock seedlings, for example, tend to grow where there is some protection from herbivores. This can be caused by slash within the cutblocks that may also provide structure for wind-dispersed seeds to settle out in. The size and distribution of areas unsuitable for planting, such as large logs and other debris, rock outcrops, small wetlands and other localised areas unsuitable for planting or tree regeneration could also create apparent aggregation among conifers. This is simply because part of the area is unavailable for growth and density within the plantable areas of the block would be higher than the block average.

The local effects of grazing can be quite variable, and can depend on the interaction between the spatial patterns of grazing and the preexistent vegetation. As a result, grazing can sometimes increase, and sometimes decrease, spatial vegetation heterogeneity (Adler *et al*., 2001). Age may also affect apparent conifer distribution. The test areas were planted between one and fourteen years before surveys took place, but the intensity of grazing has been shown to peak at around eight to eleven years after planting (Harper, 1968). The intensity of grazing would therefore be expected to vary between areas; however, h_T values were shown to be uncorrelated with age of the block, suggesting that this was not the case. Due to uncontrolled factors such as these, determining the cause of aggregation seen in some of the blocks in this study is beyond the scope of the present investigation.

Observations made during this study suggest that elk may prefer low gradient, low elevation areas close to major water sources and away from roads. This is consistent with several other studies. In a study that measured an extensive number of variables determining habitat use by elk in western Montana, for example, the most important variables were slope, the amount of foraging area within 200m of each location, and the distance to roads and human disturbances (Edge *et al*., 1987). Similarly, another study in Montana found that habitat use by elk was positively correlated with distance from roads and negatively correlated with distance from cover (Grover and Thompson, 1986). In Idaho, elk preferred areas greater

than 400m away from the closest roads in all seasons, and analysis of home ranges showed that they contained more foraging area and less thermal and hiding cover than was available (Irwin and Peek, 1983). This is consistent with Koshowski (1999), who found that elk preferentially used young (8-19 yrs.), stocked (1-7 yrs.) and swamp habitats and avoided mature habitats (>120 yrs.). In a study with over 100,000 locations from 60 elk, it was found that selection ratios increased with increasing distance from roads (Rowland *et al*., 2000). These results varied between seasons, but not between individuals or years. Unsworth *et al*. (1998) found that in the winter cows preferred moderately steep west or south facing areas at low to mid elevations and that bulls more often used benches and open ridgetop areas on the upper portion of slopes, and that, in general, elk in areas with roads tended to use areas with more cover. Female Roosevelt elk in Oregon used brushy clear-cuts more than open ones, preferred southern aspects throughout the year and never ventured far from the forest / clear-cut edge; in calving season they spent more time in cover and used lower elevation areas closer to water than the rest of the season (Witmer and Decalesta, 1983).

Information gathered during the study suggests that elk are widespread throughout the study area. Within TFL#37 and FLA19233, only two drainages, the Kilpala River drainage and the Karmutzen Creek drainage, were identified as not having elk use / populations. Since elk are so widespread in the study area, it becomes more difficult to identify those areas in which elk damage is likely to be highest in regenerating forest stands.

Developing a model predicting high elk damage proved to be beyond the scope of the current study. However, the data gathered during this study and Denise Koshowski's 1996-1998 study may provide useful supporting data for further predictive analysis or research. Statistical methodology exists that can be used to compare use and availability of habitat types. Aldlredge and Ratti (1986) compare four methods of determining habitat selection, but caution that at least 1000 data points (20 animals * 50 locations) are needed to suitably decrease the probability of Type II error and that the number of variables used in the analyses should be limited to as few as necessary. Thomas and Taylor (1990) review three methods of comparing habitat use and availability, and Johnson (1980) also provides a methodology. Local knowledge can also be useful in predicting future habitat use by elk. Holthausen *et al*. (1994) suggest that expert opinion is a reliable predictor of elk habitat suitability in most situations, but caution that opinion should be used as a method to validate empirical field studies.

Conifer seedlings need to be protected from elk damage to improve survival and growth, and allow cutblocks to achieve a free-to-grow status (i.e., free from the pressures of browse and damage caused by ungulates and other animals, as well as competition from other plant species). Browse protection has been used in TFL#37 and FLA19233 with limited success, but problems continue in high elk use areas, obliging Canfor to spend excessive time and effort on re-planting these areas, sometimes numerous times (table 1). The present silvicultural system likely encourages browse by ungulates by providing suitable disturbed habitat close to cover with an ample food supply (Reimoser and Gossow, 1996). This is reflected in the fact that elk preferentially use young re-forested stands over mature forest (Harper, 1968; Koshowski, 1999).

Some strategies may exist to reduce potential impact on regenerating seedlings. Planting seedlings in clumps may help to protect seedlings in the center of the clump. In Minnesota, for example, planting white spruce and balsam fir in large clumps tended to shelter white pine from browsing by white-tailed deer and snowshoe hare (Anderson *et al*., 2002). Roosevelt elk, however, are much larger animals, and may not be prevented from reaching the middle of the clump.

Some species are clearly much more resistant to browse than others. Results from this study strongly suggest that elk prefer western redcedar and yellow cedar, when available, over other tree species, while Amabalis fir (*Abies amabilis*), Douglas fir (*Psuedotguga menziesii*) and Sitka spruce (*Picea* sitchensis) were browsed much less frequently (table 2). Silviculture prescriptions could be written to reflect this preference by prescribing a higher proportion of browse-resistant species.

Planting preferred browse species such as forbs and shrubs could also reduce the demand on conifers (Brunt, 1987) and allow conifer seedlings to reach the free-to-grow status more quickly. It is not known, however, what the potential costs of this method might be.

Physical protection for seedlings from elk may provide the best alternative. Large amounts of slash are often left in cutblocks following logging. This slash could be formed into piles into which seedlings could be planted. Under this scenario, large, dense clumps of trees would be planted within cutblocks with areas of relatively low density of seedlings, preferably of browse-resistant species, in between. These piles would likely prevent elk from reaching the seedlings and therefore protect them until they reach a free-to-grow status. The piles could also provide nesting and foraging habitat for small vertebrates such as rodents, amphibians and reptiles, and would help to regenerate the soil upon decomposition. Further, cover would be provided for elk and deer without compromising their habitat.

The current regulatory framework, however, prevents many of these techniques from being used. Ministry of Forests guidelines require a consistent density of seedlings over the entire cutblock, planted with species similar to those present before logging. Forest managers are therefore prevented from adapting new standards in these situations unless alternative planting techniques are accepted by the Ministry of Forests. Given a predictive model that would identify areas of high damage likely from elk use, exceptions could be made that would allow managers to choose options that would encourage the growth of seedlings without compromising important wildlife habitat.

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